Composite Hybrid Isogrid Mirror (CHIM) Phase I Review

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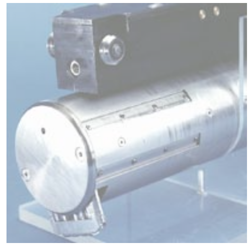
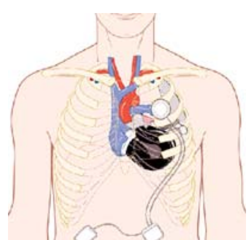
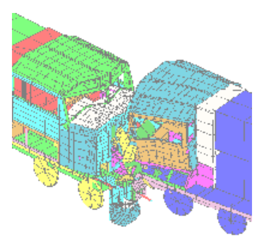
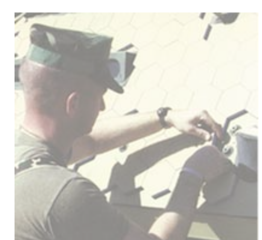
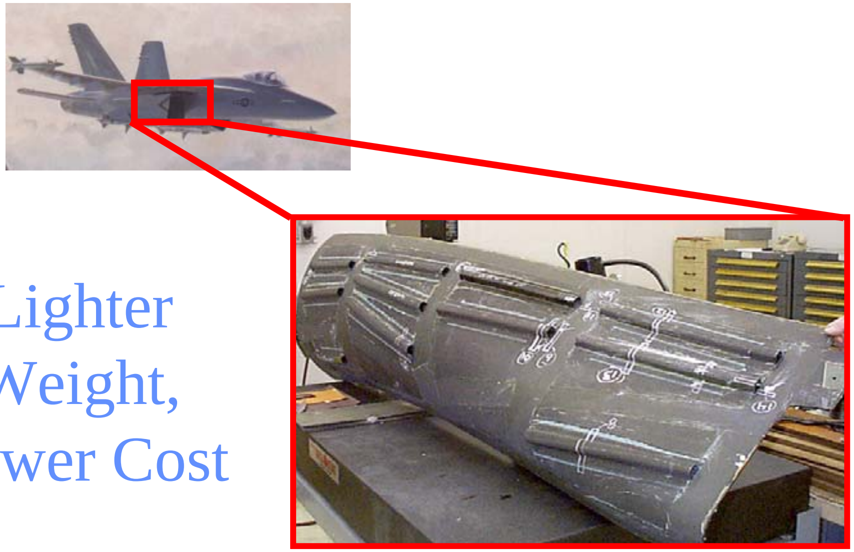



Foster-Miller: 45 Years of Innovation and Engineering Excellence




Foster-Miller Aerospace Structures

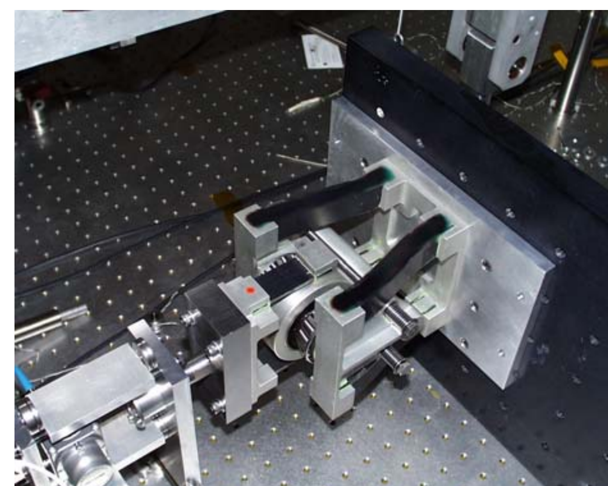


Lighter Weight, Lower Cost

Higher Precision

More Efficient

Stronger



Composite Hybrid Isogrid Mirror Program Overview

- Outgrowth of high efficiency structures research at Foster-Miller and thin glass polishing at Kodak
- Two significant innovations in one program
  - Lightweight composite isogrid truss core material to support thin glass reflecting surface
  - Removable mandrel provides glass support for polishing of very thin glass reflecting surface without quilting
- Potential performance of 1.2 kg/m^2 for a 1.5 meter diameter optic with 150 Hz free-free first mode
- Development Team
  - Foster-Miller, Inc.: Structural design and fabrication, mandrel development
  - Eastman Kodak: Optical systems, mirror processing technology, and high performance resin developer
  - University of Colorado: Precision structural testing

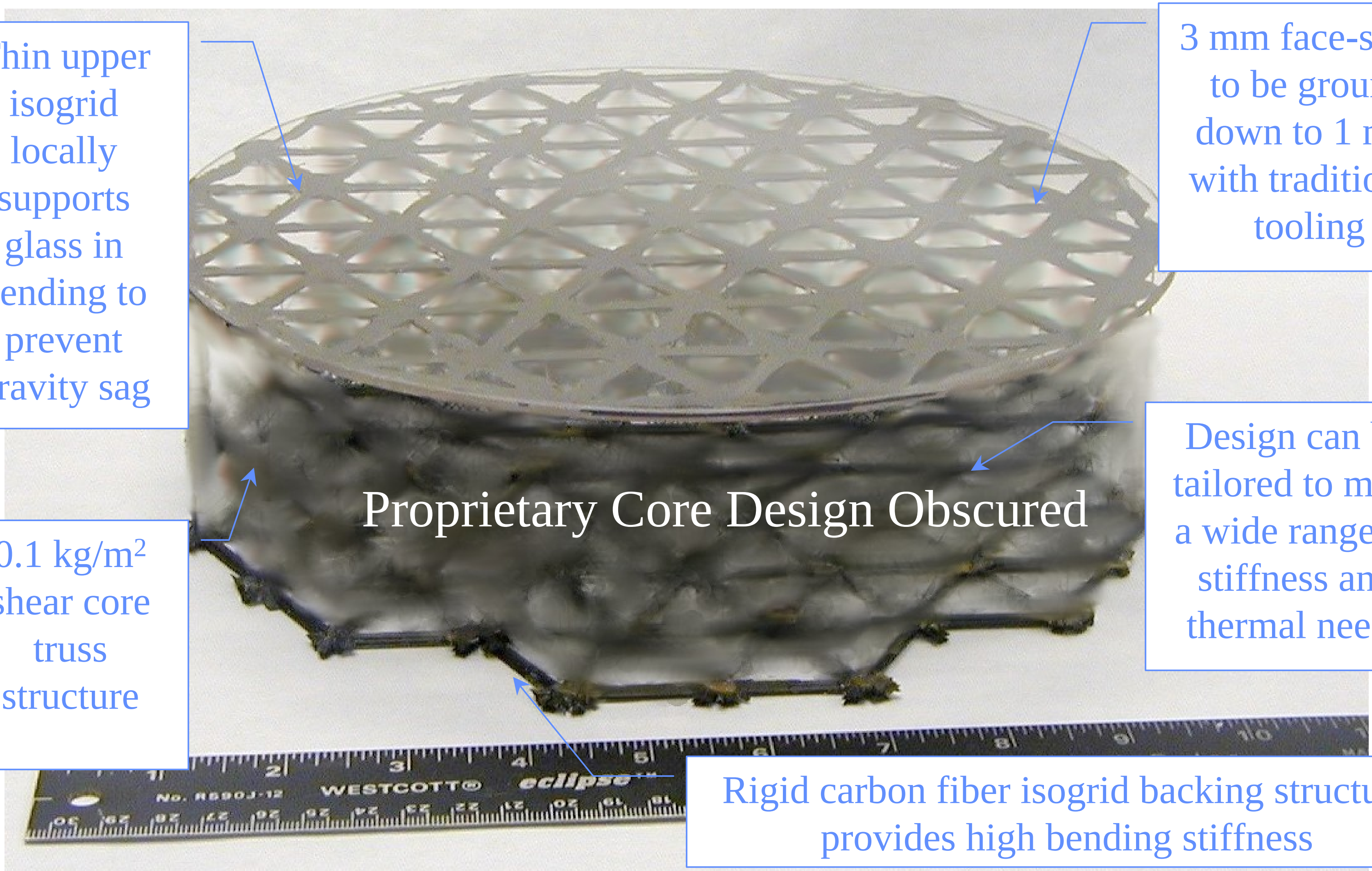
Structural Design Applies High Efficiency Space Structures Lessons to Mirror Core Materials

- **Thin glass facesheet reflecting surface**
  - Glass is polished as thin as possible (1 mm or less)
  - Traditional grind, polish, and coating technologies are used to reduce risk and cost
- **Glass is supported by isogrid truss shear core**
  - Truss design is tailored to specific mission
  - Stiffness, density, strength can all be adjusted by altering truss parameters
- **Back of "sandwich" mirror structure is formed by composite isogrid**

9.5” Phase I Prototype

Thin upper isogrid locally supports glass in bending to prevent gravity sag

3 mm face-sheet to be ground down to 1 mm with traditional tooling

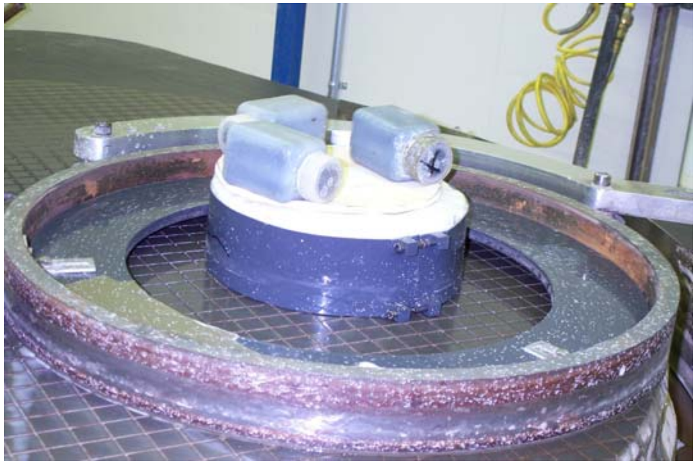


Design can be tailored to meet a wide range of stiffness and thermal needs

0.1 kg/m^2 shear core truss structure

Rigid carbon fiber isogrid backing structure provides high bending stiffness

Removable mandrel is used to support glass face during grind and polish

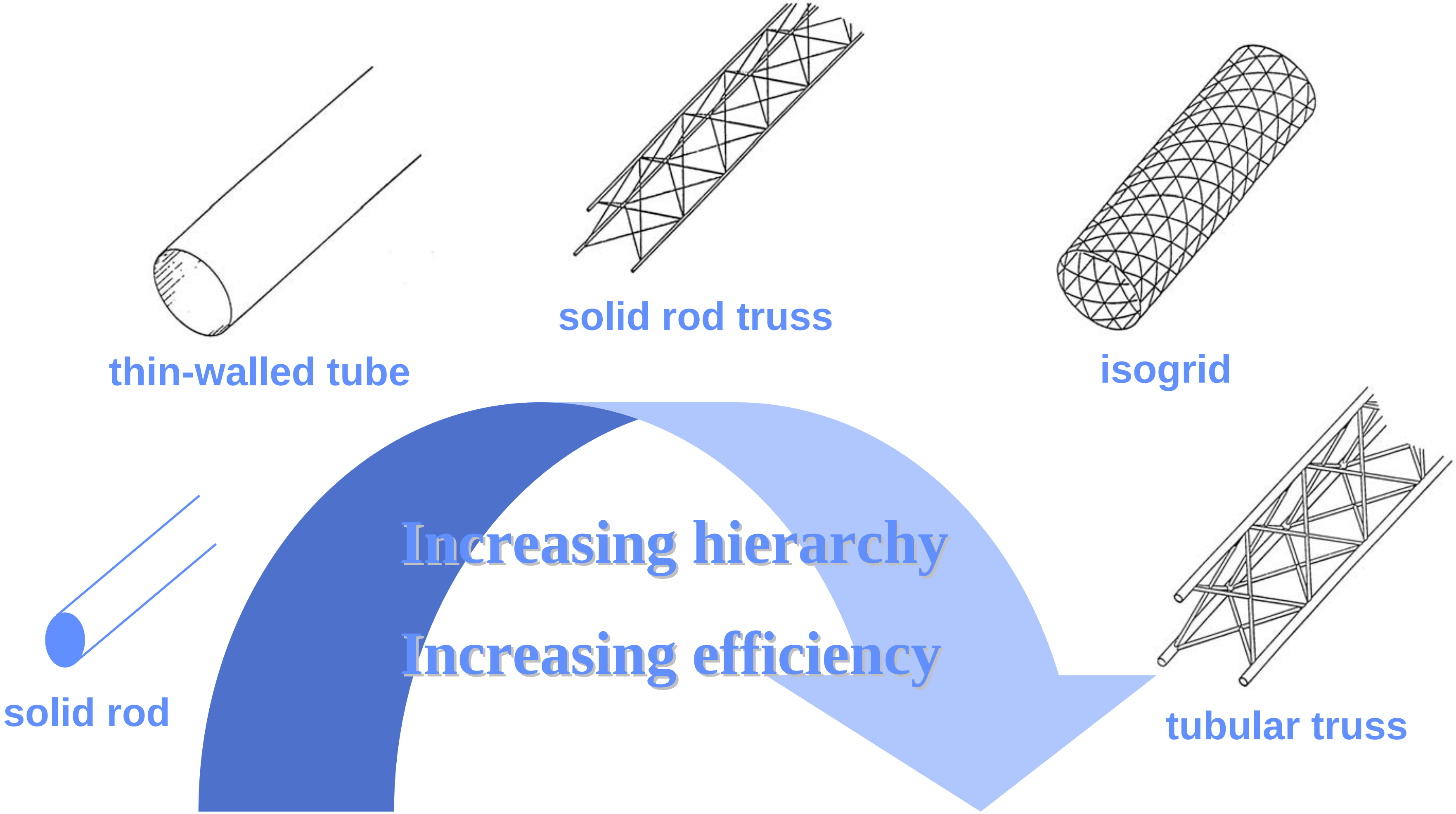


- Provides even support of glass face sheet during grind and polish
- Allows use of traditional grind and and polish tooling, no special mirror processing steps required
- Will greatly reduce cost of mechanical steps of mirror production and handling; thin glass is never left unsupported
- Designed to eliminate quilting/pincushion
- Mandrel construction can be tailored to meet both the shape of the optic and the material characteristics of the face-sheet and composite backing structure
- Mandrel fabrication, installation and removal is rapid and low cost

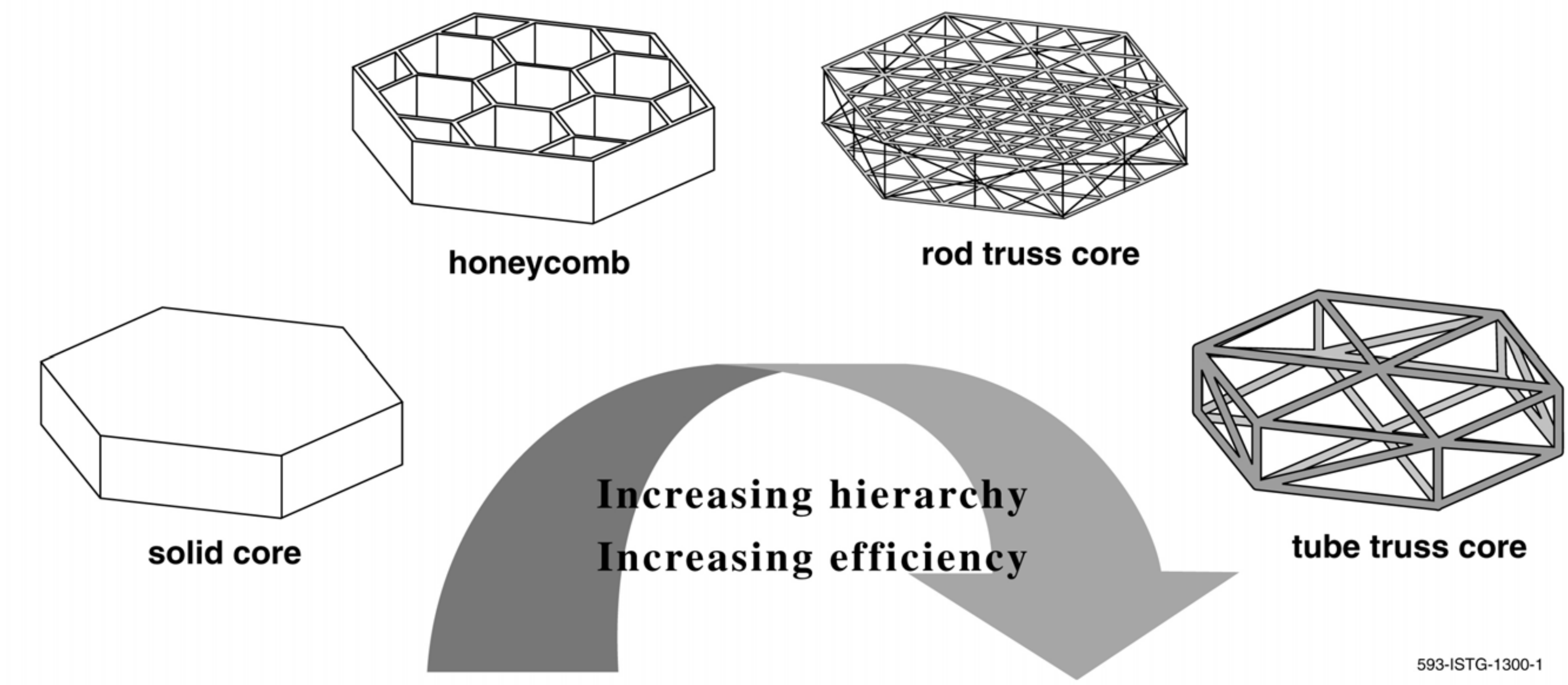
Advantages of the CHIM Approach

- Extremely mass efficient
  - Trusses are more efficient in lightly loaded structures than foamed solid cores or honeycombs
  - Very low average density through concentration of material
  - For a 1.2 kg/m2 optic, only 27% of the mass is the composite backing structure, the rest is glass
  - Lower bounds of areal density limited only by how thin glass can be ground
  - Structure is efficient even at high glass thicknesses and loads
- Enables use of all axial carbon fibers and fiber blends
  - Very high specific stiffness
  - Reduces CTE matching to a single DOF problem
- Thin glass meniscus never have to be handled without being completely supported
- Does not require development of new polishing and coating technologies

Why a truss core? “Extending the efficiency of lightly-loaded structures often requires increasing their architectural complexity”, Mikulas 2000



Same structural rules apply to core structures



Phase I SBIR Program

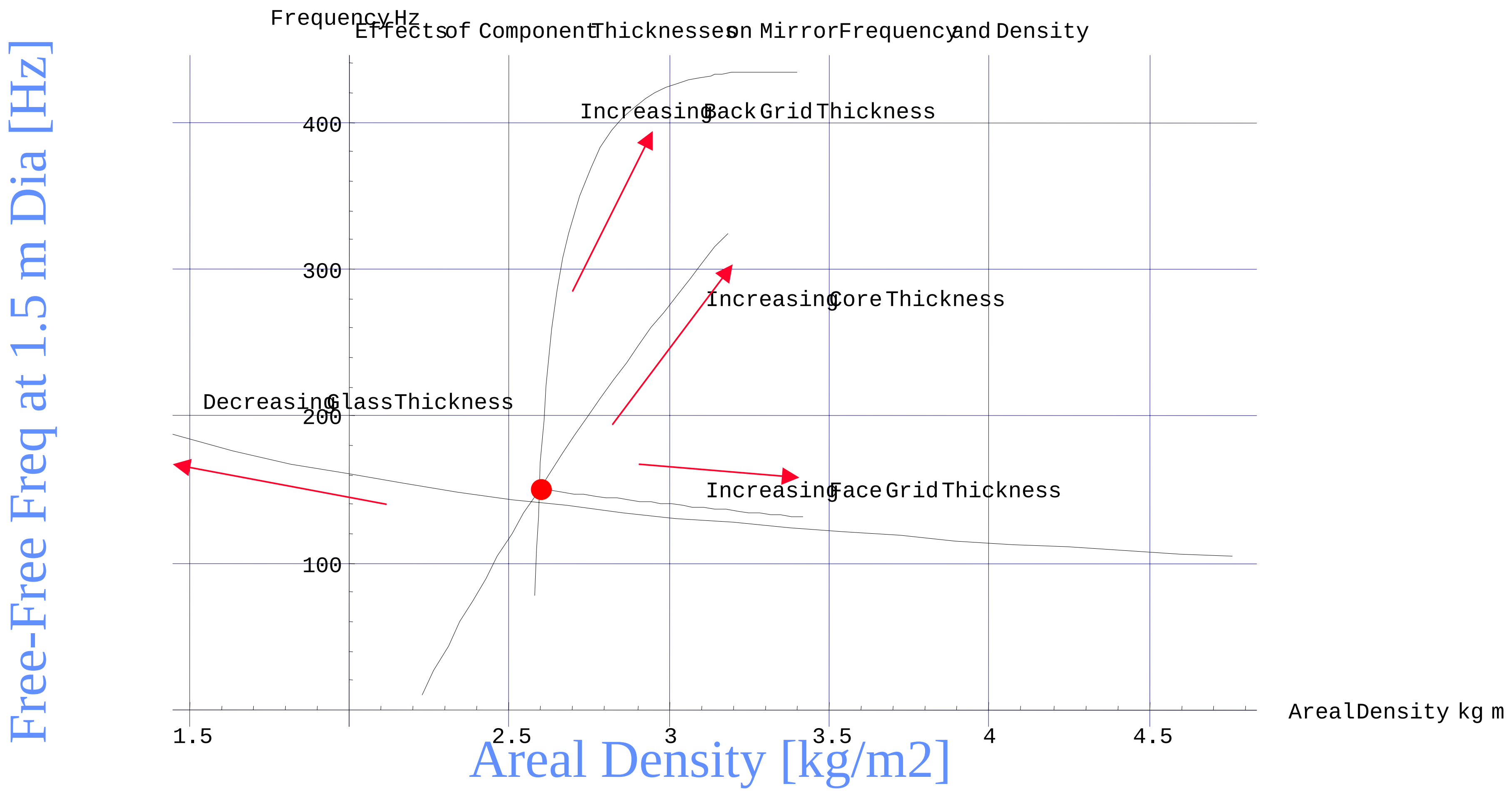
- **Focused on…**
  - System design
  - Structural manufacturing
  - Crude thermal survivability testing
  - Mandrel manufacturing
  - Demonstration of grinding and polishing
- **Deferred development of…**
  - Traditional low CTE composite fiber blends for truss rods
  - Inclusion of existing low CME resins
  - Use of low CTE/CME adhesive
- **Results**
  - 3 kg/m2 prototype (2.7 kg/m2 for ULE) with 1mm thick facesheet
  - Were able to grind and polish, some strains imparted by mandrel

System Design

- Developed design laws based on well established truss design techniques
- Showed impact of system design parameters on mass and stiffness
- Developed point design based on 1.5 meter diameter optic with a 150 Hz first mode
- Started with 1mm thick facesheet and designed structure to suit
- Glass dominates areal density
- Decreasing the glass thickness provides mass savings in back structure to achieve same stiffness
- With 0.5 mm glass, areal density is 1.2 kg/m2
- Other design options could further reduce core mass

Component	Areal density
1 mm thick ULE Glass	2.2 kg/m2
Isogrid core	0.1 kg/m2
Isogrid back	0.3 kg/m2
Glass-composite bond	0.1 kg/m2
Total	2.7 kg/m2

Approach provides a great deal of design flexibility and control



Crude thermal test shows survivability

- Analysis of ABL requirements indicated that glass temp would start at
  -70°F and rise 2.5°F per second during firing.
- Would equilibrate at 70°F under continuous illumination
- Fabricated sample of glass/bond/carbon
- Cold soaked in LN2 (-321°F)
- Heated with welding torch to +130°F at 4 times the rate of ABL heating
- No structural failures
- Thermal distortion was not measured
- “Existence Proof”

Phase I Results

- Design analysis shows structural efficiency and wide range of applicability (ground, air and space systems)
- Phase I manufacturing shows ease and low cost of production
  - Combines existing manufacturing techniques rather than developing entirely new processes
  - First two different 9.5” prototypes constructed in 2 months
- Phase I prototype shows structural efficiency
  - Section of a 1.5 meter, 150Hz point design
  - 3 kg/m2 (2.7 kg/m2 with ULE)
  - Potential for 1.2 kg/m2 with further grinding
- Mandrel allowed grind and polish of ultra-lightweight (0.75 ounce) structure
- Future work goals identified